"PRELIMINARY DESIGN OF THE MECHANICAL TO ELECTRICAL CODING CONVERSION FOR A TYPEWRITER TO BRAILLER CONVERTER"

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PRELIMINARY DESIGN OF
THE MECHANICAL TO ELECTRICAL
CODING CONVERSION FOR
A TYPEWRITER TO BRAILLER CONVERTER

by

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ABSTRACT

In this report a preliminary design of the mechanical to electrical coding conversion for a typewriter to brailler converter is presented. The device consists of a set of coded shades which attach to the key mechanism of a typewriter. These shades, when moved, interrupt light beams to produce an electrical output coded in braille.

INTRODUCTION

It has long been felt that the handicapped individuals of society have much to contribute to the world but are at present not being utilized. Among these potentially useful groups is that of the blind. The proposed reason for this loss of talent is a lack of communication. Louis Braille's system of communication for the blind has enabled these people to communicate with each other without much difficulty. However, the difficulty in communication between sighted persons and the blind has not been greatly reduced. The reason for this difficulty in communication between sighted and blind comes from the necessity of both of those communicating to know the braille code. The present braille producing device usually consists of a typewriter-like device which has six keys and a space bar rather than the conventional letter keyboard that the typewriters have. In order to produce the braille, the individual must "compose" the braille symbol he wishes to have. By pressing a combination of the six keys before him, the communicator produces a combination of the six possible raised dots on the paper (see Appendix A for illustration of code and braillers).

These braille writers are manually operated and require much effort to operate. The need, therefore, is for a device which will allow individuals to use popular means of commumication to communicate with the blind. A machine is desired that can translate standard written communication into the braille code, or any similar code. There are two obvious

attacks to this problem. The first such attack is to take the written message and have the machine recognize the characters contained therein and transcribe them into braille. The second attack is to produce the braille at the same place and time as the written message is produced by linking the mechanical mechanism which produces the written message directly to the braille producing apparatus. The braille apparatus must then recognize a given movement as belonging to some standard character and transcribe it into the new code.

The writing machine here considered is the typewriter and the movements mentioned are the character-key movements. This second attack to the production of braille is the one chosen for investigation in this report. It is intended that a slave braille mechanism be attached to a standard typewriter in such a manner that when the typewriter is operated a message in braille is produced in addition to the regular typewritten message. In this manner, any individual, sighted or blind, who has a knowledge of the typewriter can produce messages in braille at a speed equal to that commonly attained in typewritten communication.

There are several immediate applications of this idea that come to mind. In the academic world, blind students will be able to have written material transcribed by fellow sighted students into the braille code thus enabling them to retain on paper the material they wish to have available for future reference. The next area of application for such

a braille transcriber is that of the business world. Heretofor the talents of the blind have not been greatly utilized because of the inability of general internal plant communication to effectively be used for all employees when some of them are not sighted. With a machine which can automatically produce braille for the blind members of the organization, the communication with the blind would become much less of a problem.

The braille transcribing machine or Typewriter to Brailler Converter is easily divided into two parts. The first part is the communication with the twpewriter and the second is the actual production of braille at high speeds. It is the purpose of this thesis to perform the preliminary designing, building and testing of the first of the above divisions of the problem.

It must be noted that there are two methods of producing braille. The first method is to have braille forms for each of the characters to be used, and when one of these characters is desired the correct form is pulled out of stock and employed. This is the same method that a typewriter uses. Serious thought about such a method in the light of the accuracy needed to fit the form and its mate results in the conclusion that the idea of using "stock forms" in the manner of a typewriter is not easily realized. It is for this reason, in part, that such a method is not employed in the present mechanical Braille-Writers. An alternate method of forming braille is to have a changeable form which can be

used for all of the characters desired. In the designing of the mechanism which communicates with the typewriter, it is assumed that the slave unit of brailler is to be of the changeable form type and therefore needs a coded signal.

DESIGN CRITERIA

The overall criteria for the device which communicates with the typewriter, turning the typewriter character-key movements into a coded signal fit for a slave brailler, are several. The first criterion is safety. This device, as any device in the normal market, must be safe for the user. The second criterion pertains to the accessory nature of the mechanism. The device must not alter the typewriter's normal function. It cannot be allowed to materially affect the operation of the typewriter as it was designed originally. The third criterion is cost. The cost of the device must not make it unobtainable to the individual for whom it is intended. Therefore it must be in the cost range of a typewriter (less than $300). The next criterion to be considered is that of simplicity of operation and ease of maintenance. The device must be reliable and not prone to breakdown. Therefore the design to be sought is that which is most simple. The fifth criterion considered is that of size. The addition of the coding mechanism should not transform the typewriter into a space consuming console. The last criterion is that of ease of adaptation to the typewriter. It is desirable, but not entirely necessary that the design provide for a simple yet reliable method for attachment to

an existing typewriter. It would be good if such attachment required neither skilled personnel for installation nor lengthy interruption of the use of the typewriter for installation. In recapitulation, therefore, the overall design criteria for the coding convertor are:

1. Safety
2. Accessory nature
3. Cost
4. Simplicity of operation and ease of maintenance
5. Ease of attachment
6. Size

The typewriter chosen for adaptation is the Smith-Corona Portable Electric. The reasons for this choice are first, its low cost (less than $200) and second, its high speed or rate of typing.

PROPOSED DESIGN

EVOLUTION OF BASIC PRINCIPLE

The first and most obvious method of turning the movements of the typewriter keys into the braille code is to connect small switches to the keys themselves. This would involve the purchase of 46 such microswitches and a coded relay with each one to perform the braille-writing. The cost of these components alone trespasses our third design criterion. In addition to this fault are first the load that these switches put on the existing typewriter mechanism and second the possibility of mechanical breakdown.

It was in contemplating the problem of loading the existing typewriter mechanism that the idea of using light was first proposed. The idea of moving a light-weight opaque shade in the way of a light beam obviates the problem of loading the typewriter mechanism. Normally the light beam would fall on a photocell which through an electronic circuit would produce a usable signal when the light was interrupted. But even with this system the problem of cost is not avoided since the photocells would cost the same as the microswitches proposed in the above design, and the expensive relays would still be present.

The present system of multiple beam coding was then considered. Since the weight of the shade can be neglected in the first analysis of the advisability of this system, it would not matter any more if more than one light beam were interrupted. Therefore if there were a possibility of inter-

rupting up to six light beams, these light beams could themselves be used to perform the coding. That is to say, the shade which is connected to each key can be shaped such that it interrupts a different number of light beams than any other such shade. Therefore the braille code for each key could be represented on its respective shade.

The next step is the solution of the problem of capitalization. Each of the letters of the alphabet are the same in the upper case in braille as in the lower case except for the use of an additional character which tells the reader to capitalize the symbol in question. (See Appendix "A" concerning capitalization). Since the upper case of the alphabet is the same as that of the lower case except for the capitalization addition, it would be simple to make some contact with the shift key of the typewriter which would perform the capitalizing operation whenever it is actuated. There is one defeating drawback to this proposal. On the typewriter, the upper case for the numerals are not the same as the lower case. That is to say, the capital two is the quotation mark on some typewriters and the capital four is the dollar sign. Therefore, to have a simple switch under the shift key in the typewriter to perform the switching to upper case in braille will not suffice.

It can be seen from figure 1 that this difficulty with the upper case only occurs with four characters appearing in the number row of the typewriter. However for the sake of these four exceptions a modification of the shade system

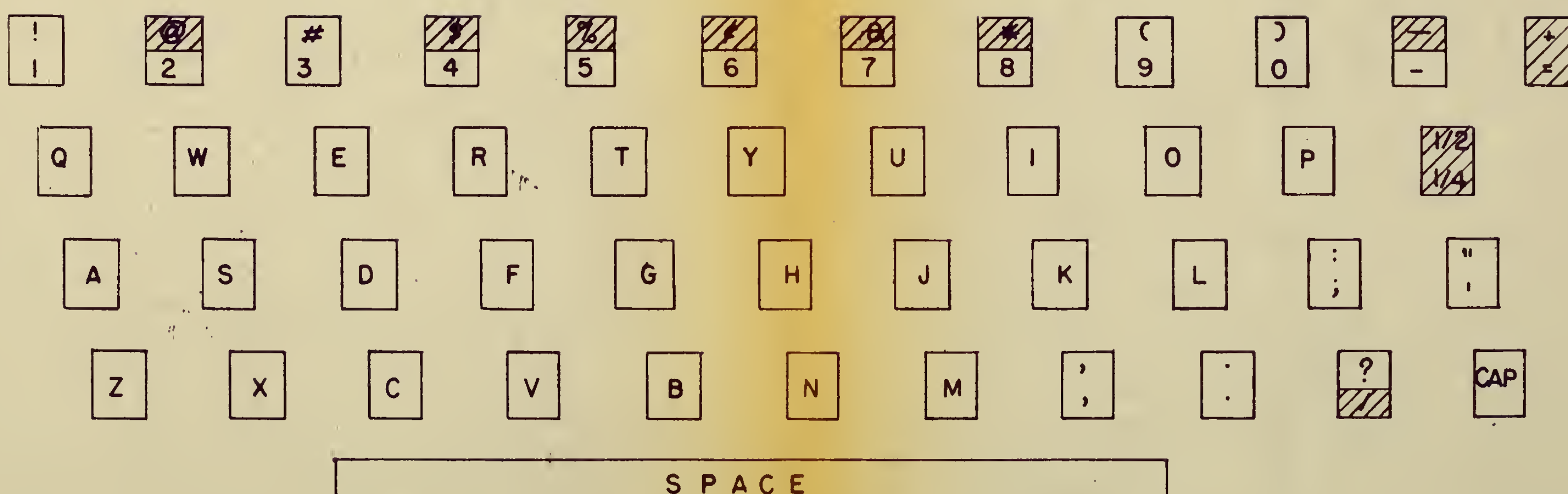

FIGURE I: COINCIDENCE OF BRAILLE & TYPE CHARACTERS, LACK OF EQUAL

became necessary. Rather than interrupt just six possible light beams the number now jumps to twelve. In this manner the activating of the shift key on the typewriter allows the electronic circuitry to be connected with either of two sets of six light beams. But this doesn't affect the desired capitalization. Another modification of the shades allows for this function. If instead of two groups of six light beams, one were to use two groups of seven the necessary capitalization could be included in the shade code. That is, when the shift key connected the circuitry with the lower case group of light beams the regular braille code of six dots would be used, and when the upper case group of light beams was connected, the seventh dot (corresponding to capitalization) would be added where necessary.

This previous explanation will be made more clear when the shade itself is studied (see Figure 2a). The two groups of seven are realized by the seven nibs on the shade, both on top and on bottom. If the nibs are all placed on one side of the shade only eleven light beams are necessary. The coding is obtained by passing light beams perpendicular to the shades, and between the nibs when they are stacked beside each other (see Fig. 3). Then when one shade is slid it will interrupt a combination of light beams corresponding to its remaining nibs (see Fig. 4).

The theory of the device, then, is to shine a parallel beam of light on the end of a stack of shades. This stack will divide the beam up into fourteen smaller beams which can

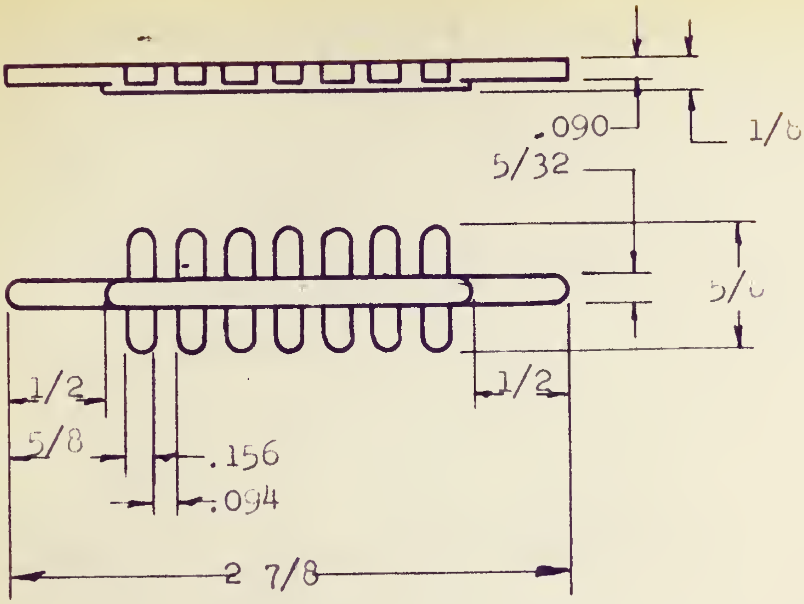

FIGURE 2a:
UNCODED CODE KEY
DIMENSIONS IN IN.

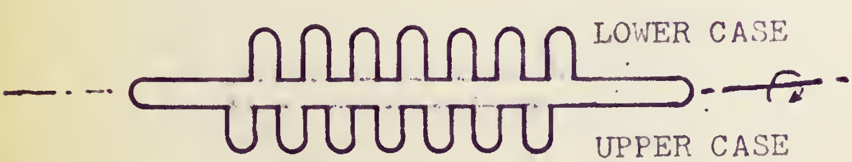

FIGURE 2b:
SHIFT CODE KEY
(ROTATED 180°)

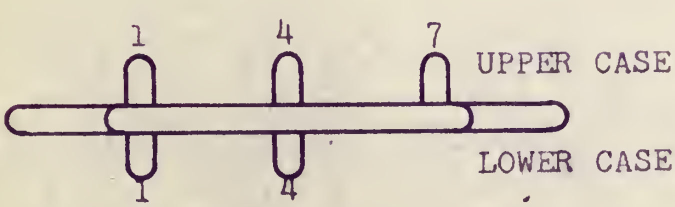

FIGURE 2c:
KEY CODED FOR
LETTER "C"
(NIBS NUMBERED)

Figure 3 is located on page 32.

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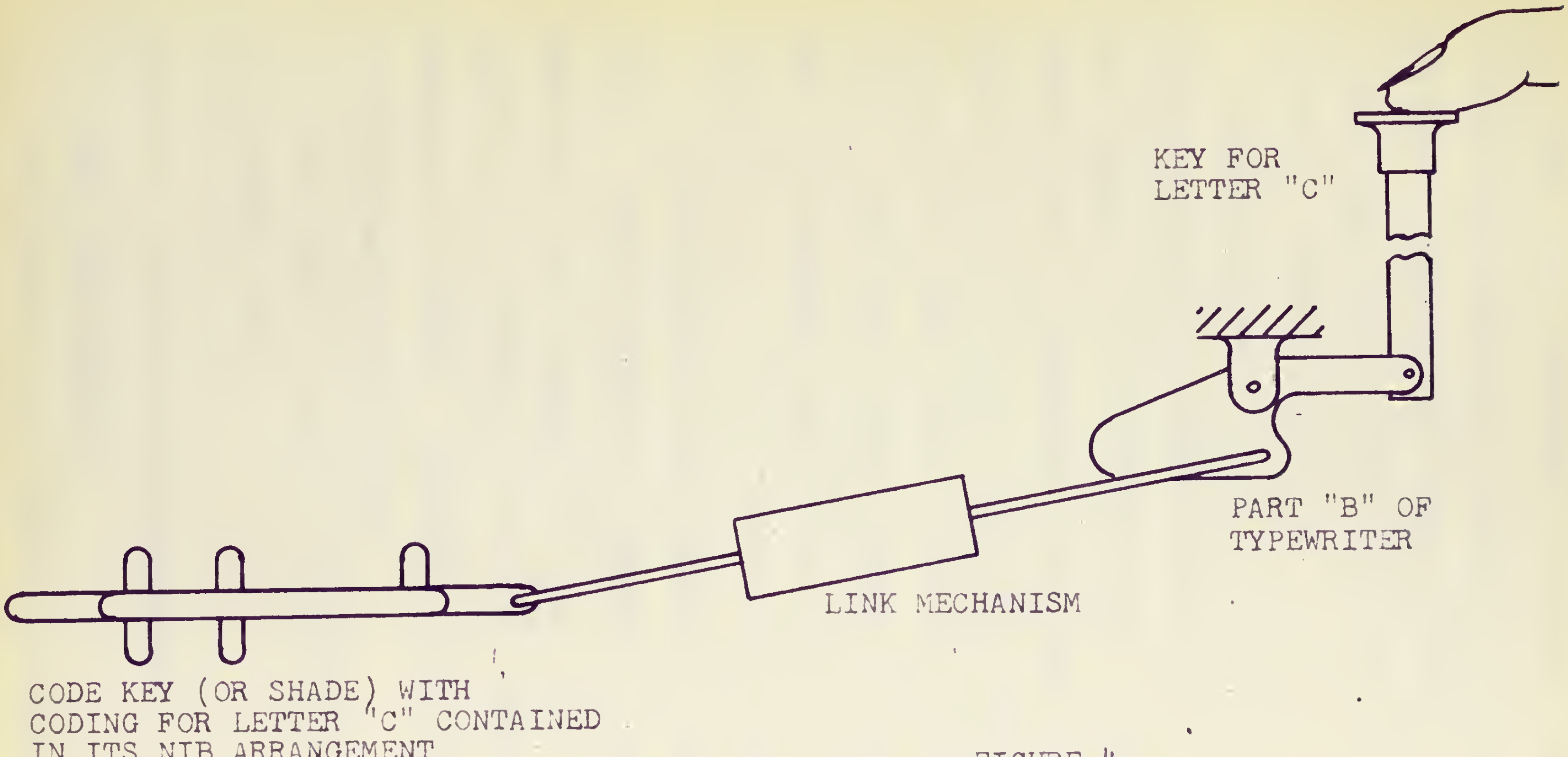


FIGURE 4

DIAGRAM OF KEY TO SHADE CONNECTION

then be interrupted in code by the key desired. The arrangement chosen is illustrated in figures 3 and 5. Both rows of seven light beams are focused on the one set of seven photocells. However the shade connected to the shift key selects which row of seven beams is allowed to strike the photocells (see Fig. 2b).

The capitalization has now been provided for. There is another important operation which has not been attended to. That operation is the letter space. There are enough spare combinations to use another code key which would, with the aid of a logic circuit, convey the signal for a letter space to the slave unit. This is not the method chosen in this design. Instead a regular switch is suggested for this purpose. This switch will be attached to the space bar of the typewriter and will be connected by a wire to the slave unit.

The function of line spacing is omitted from consideration. Since a message in braille is approximately twice the size of one in standard type, it is supposed that the brailler will perform its own line spacing when the end of its page is reached. Similarly the functions of tabulation and backspacing are omitted.

In figure 6 is shown a schematic of the whole design as presented above.

LAYOUT OF MECHANISM WITH COMPONENTS

Code Keys (Shades)

The design of the code keys (shades) is such as to facilitate manufacture and thus lower their cost. The

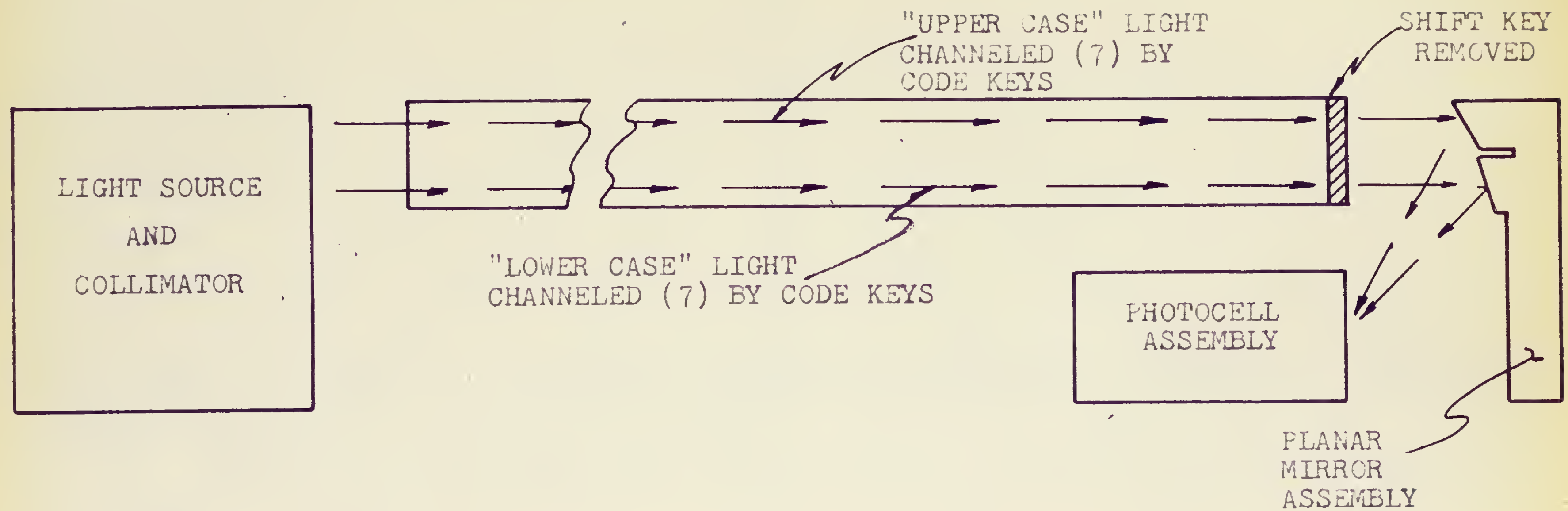
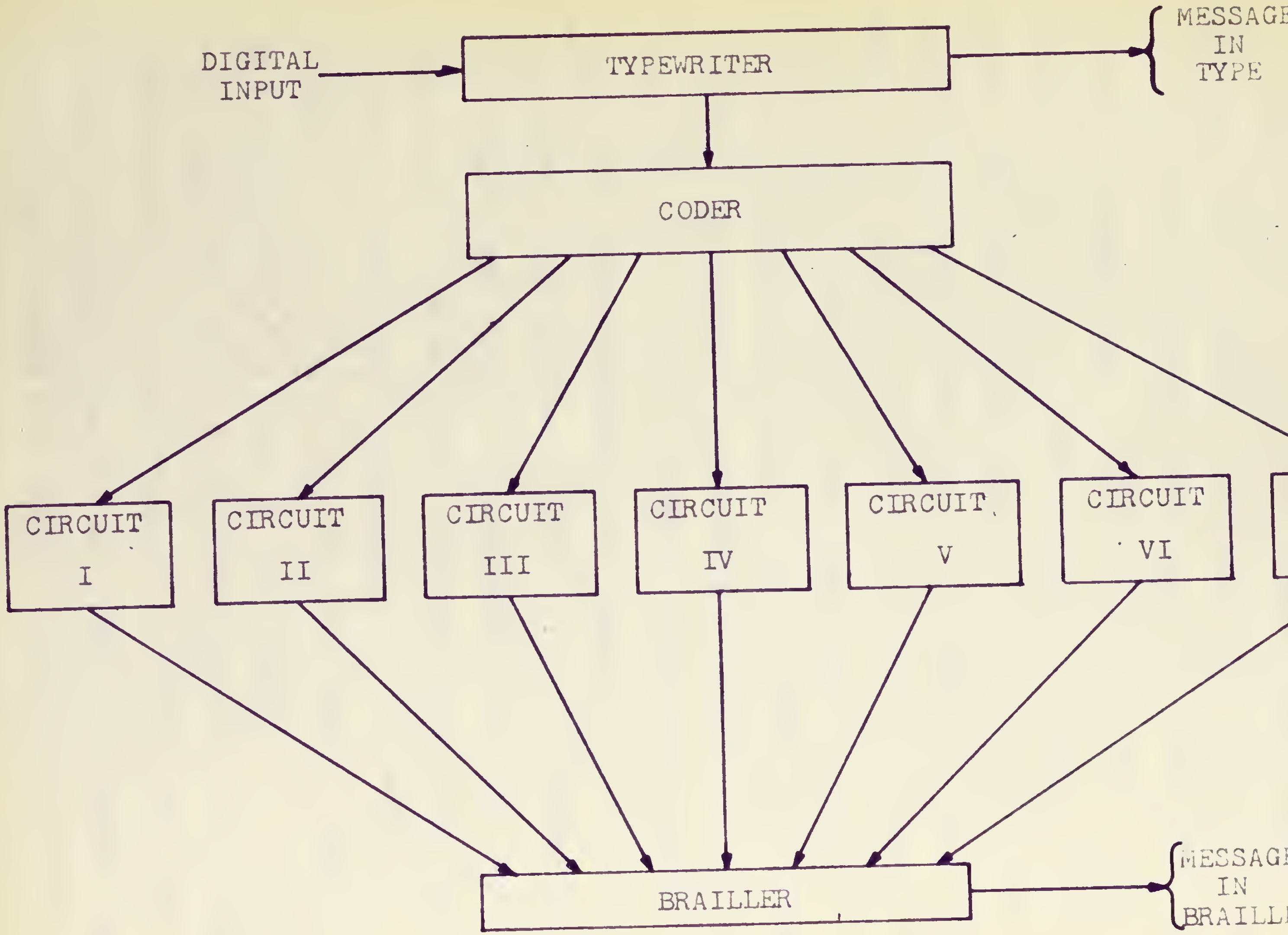


FIGURE 5: SKETCH OF CODE MECHANISM OPERATION



<u>FIGURE 6</u>; INFORMATION FLOW DIAGRAM FOR THE TYPEWRITER TO BRAILLER CONVERTER

material can be cast plastic and should be opaque with a dull finish so as to reduce reflections in the device.

Light Source

Considerable thought was given to the production of a parallel beam of light. A separate light source for each of the fourteen channels could have been used had it not been for the existence of our second criterion. This criterion is that of simplicity of design and ease of maintenance. With such a great number of light sources the probability of a partial failure of the device would be rather high. This type of failure is worse than a complete one since a false code would result without the operator knowing of it. Certainly it would be more desirable for a total breakdown thus giving the operator no reason for working under the false assumption that everything is working properly. Therefore separate light sources were not seriously considered. The smallest number of light sources possible was sought, and the most obvious answer is one light source. The result of contemplating this solution is the device as presented, having one light source at the focus of a parabolic mirror. A low voltage lamp is to be used in order to prevent the possibility of a shock to the operator. At first thought one might think that a parabolic mirror is not the most simple solution to the problem. It is true that two linear or tubular light sources could produce the needed light, but the choice of lengths in lights on the market does not allow much minimization of space in the apparatus. The production of a parabolic mirror is not as difficult as it may seem.

There are two popular methods of making such mirrors in production. The first is that of deep drawing sheet metal and the second is that of casting plastic. In the second method, the cast plastic is subsequently coated with aluminum.

Whatever the method of producing the parabolic mirror, a small, low voltage lamp is easily placed at the focus.

Linkage System

Thus far the method of attaching the coding device to the typewriter has been ignored. Of course the method of linking the code keys (shades) to the typewriter mechanism depends on the typewriter involved. In practice it should be possible to have different sets of adaptors for the different styles of typewriters. Possibly it might not be difficult to convince the typewriter manufacturers to modify their machines slightly in order to facilitate the attachment of such under-carriage devices.

The typewriter chosen for experimental purposes has a part (sometimes referred to as part B), linked with the key motion, which is conviently exposed at the surface of the underside of the carriage. All of the keys of this typewriter have this same part located on one linear axis. That is to say, the keys of the typewriter, while forming a rather rectangular array on the keyboard, connect to a row of identical B's located at the underside of the carriage. The resulting assembly resembles the stack of code keys of the coding device itself. The spacing between code keys was chosen to correspond to the spacing between the stacked parts

mentioned above. These parts of the typewriter key mechanism perform a rotary motion which results in a horizontal component which is approximately 3/16 of an inch in magnitude (see Fig. 4). In order to use this motion to actuate a code key which may be less than this distance the linkage system in figure 7 is suggested. The spring is to be stiff enough to transmit the pulse motion of the key mechanism directly to the code key without measurable transients but it must be soft enough not to add an appreciable resistance to the key motion when overtravel is reached. Overtravel here means the travel of the key mechanism beyond that required for code key travel. Certainly a linkage system having levers to proportion these motions could be used. However such a system will require additional construction on the coding mechanism and is not presented herein but only suggested for further investigation. As for a general purpose easily adaptable mechanism, the over-ride spring mechanism seems worthy of further study.

Circuitry

The electronic circuitry illustrated in figure 8 is suggested for the purpose of turning the coded light beams into a usable electrical signal. By usable here we mean that something of the order of 1/2 inch-oz. of mechanical energy. This is at least usable in a mechanical amplifier of the sort found in electric typewriters. It is here supposed that the converting from electrical energy into mechanical energy is accomplished by the actuating of a solenoid.

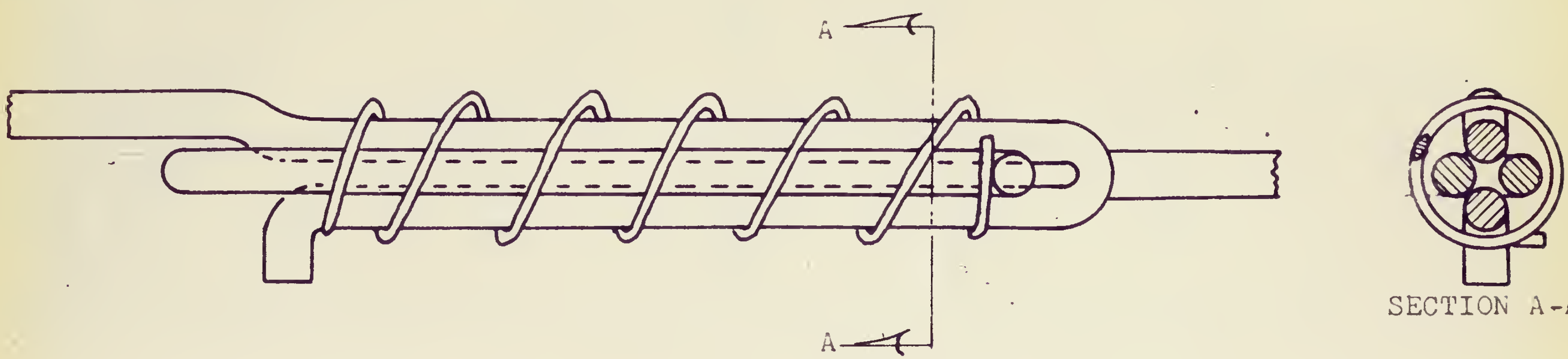


FIGURE 7: SKETCH OF LINKAGE ASSEMBLY

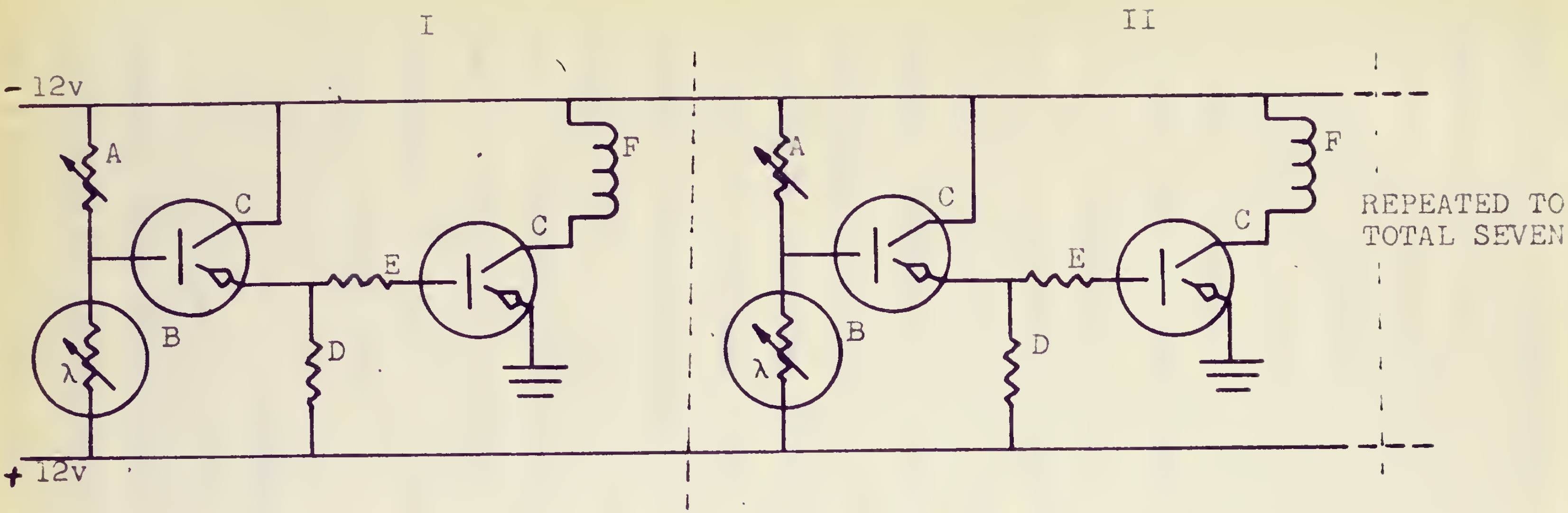


FIGURE 8: SCHEMATIC OF ELECTRONIC CIRCUITRY

The circuit consists of two stages. The first stage is an emitter follower which is controlled by its base connection to the voltage divider which consists of a photocell and a trimming potentiometer. The second stage is the switching stage which essentially acts as an off-on switch sending the second transistor from cut-off into saturation whenever the voltage of the emitter of the first stage goes from positive to negative. In other words, when the photocell changes from low resistance to high resistance the base of the first transistor changes from positive to negative. The emitter of this first transistor follows this base voltage and thus the base of the second transistor also follows this voltage. Previous to this change the second transistor was back biased, resulting in no conduction through it. After the change, however, conduction occurs and current is sent through the solenoid which is in the collector branch of the circuit. The parameters are chosen such that the second transistor is in saturation when it is conducting (see Appendix B for determination of parameters). The trimming potentiometer allows the circuit to be adjusted for best operation regardless of slight differences of the photocells from published specifications.

CONSTRUCTION

In designing a prototype, the dimensions of certain standard parts determined the size of the unit. The first consideration was the spacing between the nibs of the code key. It was decided that the photocells should be as close

to each other as possible and placed with their long axis lying in one plane. This results in the arrangement shown in the inset of figure 3. Since the photocells are to be as small as possible and still have a large resistance range, the Clairex 604L photocell, which is 1/4 inch in diameter, was chosen. Approximately half of this distance is the diameter of the light sensitive area. Therefore the nibs on the code keys must be at least 1/8 inch wide and cannot be closer than 1/4 inch to each other (measured on centers). The width of the nibs was chosen to be 5/32 inch and the spacing was selected as 1/4 inch (see Fig. 2a).

With these dimensions selected, the travel of the code keys is determined. When the code key is moved, the nib area should completely cover what was previously the "betweennib" area or slot. This criterion results in a movement of 1/2 of the nib spacing or 1/8 inch. Therefore all of the dimensions of the code key have been determined except that of its height. The minimum for this quantity is determined by the diameter of the light sensitive area of the photocell. In the prototype, the nib height was chosen to be slightly less than the diameter of the photocell itself and the base for the nibs was chosen as 5/32 to facilitate the machining of the molds for these code keys.

The next part of the model to be designed was the light source. The parabolic mirror was obtained from a hand flash light, and it was trimmed so as to produce a rectangular beam. The beam of light could not include light that

came unreflected from the bulb since in the designing of this particular reflector the manufacturers allowed areas of darkness to be produced in the vicinity of the bulb. Therefore the reflector was trimmed so that the area of the bulb could be masked off from the desired beam. The result is illustrated in figure 3, page). Having the dimensions of the light source, the rest of the model's dimensions were either uniquely determined or free for choice.

The solenoid chosen for the model was the #11 made by the Guardian Company. This solenoid was found to supply more than the required pull even when operated at 1/2 the rated operating voltage. The choice of a solenoid allowed all of the circuit parameters to be determined. The transistor chosen for experiment is the 2N1501 Honeywell PNP Germanium transistor. This particular transistor was chosen because of its ruggedness, since it will allow more than twice the required .150 amperes to flow without the need of a heat sink.

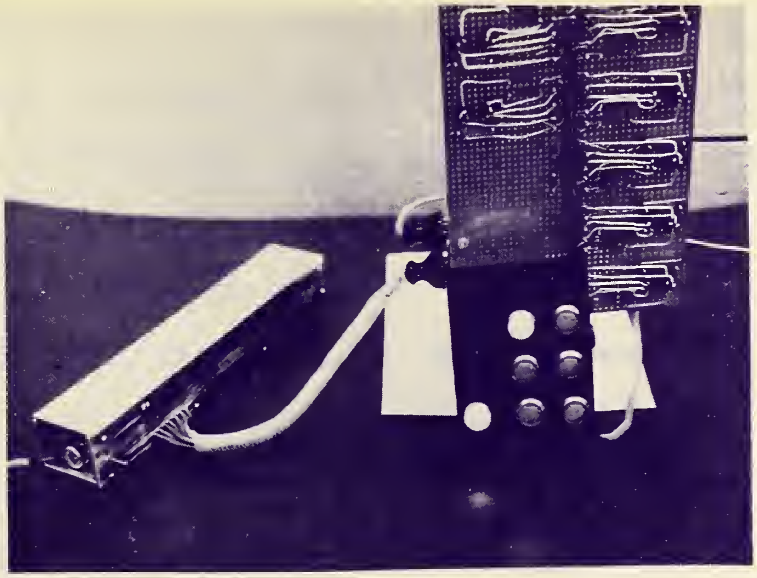
TESTING

The model was found to perform fairly well. Either the upper case or the lower case could be made to actuate the circuit by itself if the circuit was trimmed accordingly but with the circuit trimmed for one, the other would not perform satisfactorily. The explanation for this difficulty seems to lie in the existence of two different light levels for the two different cases. There are several possible solutions

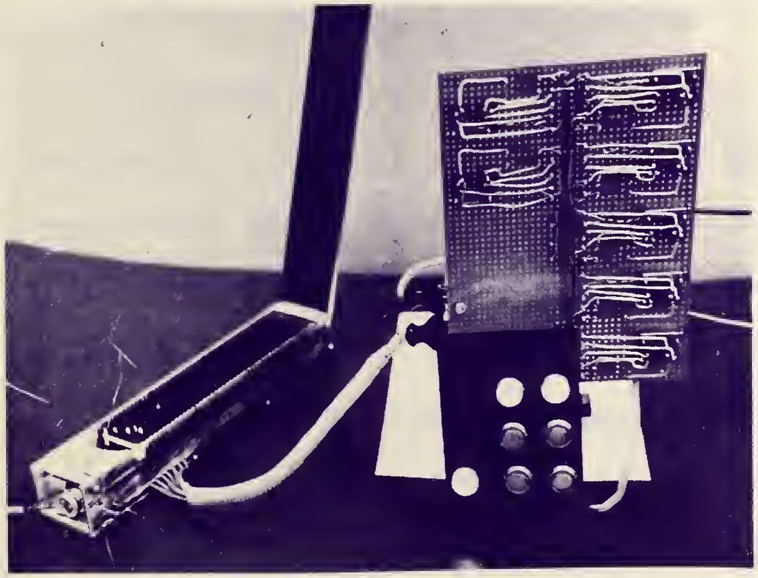
for this problem. Greater accuracy in manufacture and positioning of the parabolic mirror is one such solution and another is the addition of intensity adjusting filters for the two rows of light beams.

For display purposes the device without typewriter linkages and with pilot lights inserted in place of the solenoids was set up and tested. Pictures 1 and 2 show this set up. On the left is the code key box with the light source, code keys, and photocells. In the foreground, on the right, is the display panel with pilot lamps arranged in the form of a braille cell with one dot of the previous cell, indicating capitalization, in place. In the two pictures can be seen capital "A" and capital "B" corresponding to the keys moved in the box. Behind the display panel is a card which contains the seven switching circuits for the device.

The photocells have been tested to check their response time. In the test a trim-pot and a battery were added in series with a photocell. The voltage across the cell was displayed on an oscilloscope and the time required for the cell to change to 63% of final change was noted. The light source used in this test was the same one intended for permanent use in the device: a 4.5 volt lamp intended for hand flash light purposes. In this test, it was found that the photocells require .015 seconds to perform this change with an error in reading of .003 seconds. This time constant is considered to be sufficient to allow the device to perform correctly with the typist operating at a peak speed in excess



PICTURE 1: Prototype with display panel. Symbol for capital "A" is displayed on the panel.



PICTURE 2: Prototype without top in place. Symbol for capital "C" is displayed on the panel.

of 150 five-letter words per minute.

The next test performed was that of electrical to mechanical energy conversion. It was necessary to see if the solenoids could follow a signal comparable to that which the photocells could produce. Originally, a Guardian IR22 solenoid was chosen for this purpose. A sketch of the test apparatus is shown in figure 9. In this test a load from a spring is exerted on the solenoid and a stroke for the solenoid is chosen. Then the solenoid is given a time-varying signal and the frequency at which it begins to float is noted. For the IR22, satisfactory results were not obtained: it would not produce the desired work at the desired frequency (15 cps). It should be noted, however, that the power source gave reason to be doubted as to its reliability. Therefore the tests should be conducted again with careful attention being given to all parameters.

In addition the Guardian #11 was statically tested and found to give more than three times the required pull at the voltage intended. This solenoid has yet to be dynamically tested. It should be noted that the electrical signal given to these solenoids was a 12 volt square wave similar to that expected in the coder when in operation.

During the testing of the solenoids it was noted that the abruptness of the change of the input signal to the solenoid caused considerable inductive kick. This voltage was of the order of three times the input voltage to the solenoid. This was observed on an oscilloscope which did not have a

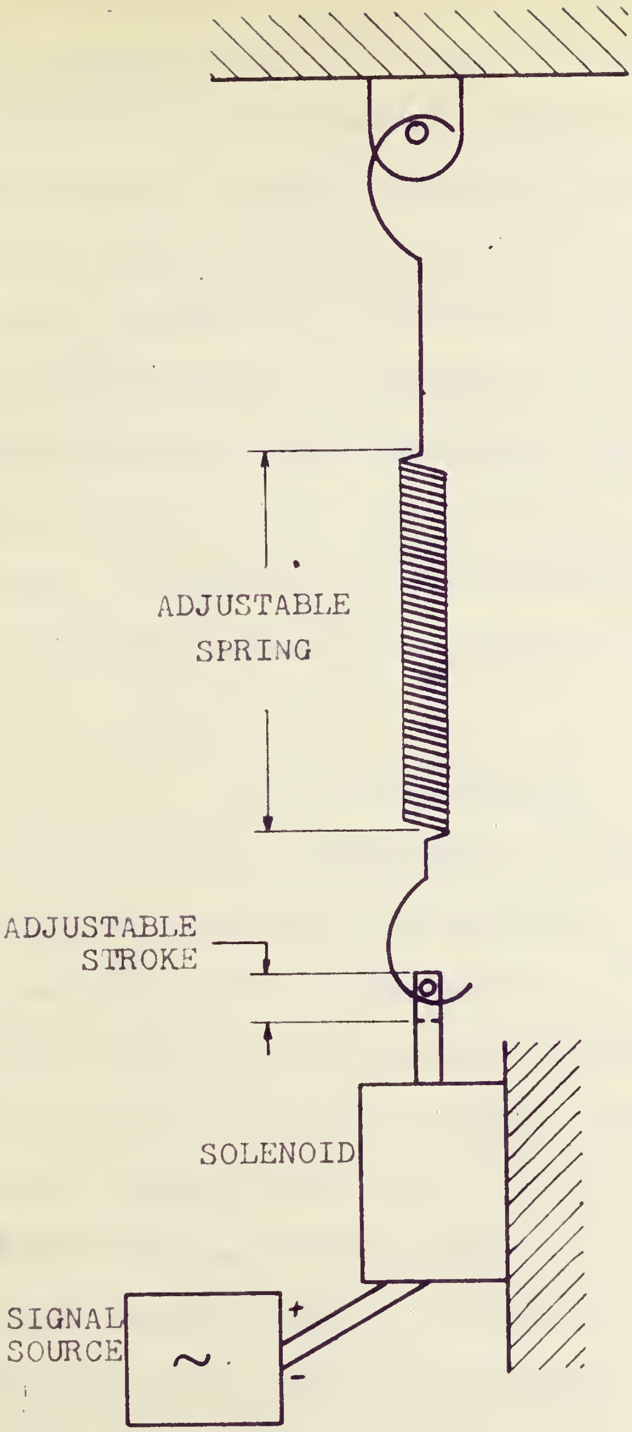


FIGURE 9

DIAGRAM OF SOLENOID
TEST MECHANISM

very good frequency response and therefore the actual kick could be greater than that noted. Since the solenoid is in series with a constant voltage source and the transistor, this voltage kick will appear inverted across the transistor. The transistor used in the test apparatus is rugged enough to take such a voltage but if in the future a transistor whose maximum characteristics approach the minimum required for the circuit were to be used (neglecting this inductive kick) the presence of such a sudden high voltage would cause failure of the device. Therefore it is recommended that a diode be added across the solenoid in order to eliminate this occurrence.

COST APPROXIMATION

A first order approximation to the cost of the coding device can be obtained by considering the cost of the more expensive components of the design. Starting with the electronic circuitry we see that it contributes three items to the cost of the overall device. These three items are the photocells, transistors, and the trimming potentiometers. In the model of the device that was built, the photocells cost $4.00 each but when a lot quantity of say ten thousand is considered, the price at the present time would come to $1.25 each. The transistors also would, in large quantity, be of the order of $1.00 each. It must be noted that the transistors here considered are not necessarily the most economical choice. The trimming potentiometers used were the TRIMIT potentiometers made by the Bourns Company. The max-

imum price expected for these is $2.00 each. In the design of one coding device there are seven photocells and trimpots and fourteen transistors. Therefore the components bring the cost of the circuitry excluding wiring (or circuit printing) and a container to a total of approximately $45.00.

Since the code keys of the unit are cast plastic and since the economics of their production is similar to that of a common hair comb, it is not unreasonable to conclude that these two costs might be of the same order. Therefore the cost of each code key is expected to be about ten cents. Similarly, the parabolic mirror is a mass produced item that in itself costs approximately thirty cents. In addition, the key linkages, although not yet completely designed nor tested, should be of the same order of magnitude. The cost of the planar mirror on the opposite end of the device to the parabolic mirror is also expected to be the same as that of the parabolic mirror since it too can be cast. Therefore the cost of the code key mechanism should come to about $15.00.

The total cost of the primary components of the whole device, therefore, comes to $60.00. In order to obtain a more accurate picture of the cost of the device, a detailed analysis would be necessary.

RECOMMENDATIONS

It is recommended that the solenoids be further tested in order to check their acceptability. If no satisfactory solenoids are found to perform with the voltages desired,

then it may be necessary to insert relays into the circuit. With such relays the switching circuitry can be simplified, thus compensating for the cost of additional components.

The transistors for the circuit can be changed to ones that approach the minimum requirements more closely. When this is done, it will be necessary to pay careful attention to maximum power dissipation incurred in the transistors while the system is switching. It is when the output transistor is between cut-off and saturation that maximum power is dissipated. A change to different transistors is actually suggested since the ones used were of such construction that their use in printed circuitry is not convenient.

Investigation of the light source is also suggested. It might prove more desirable to use lenses rather than a reflector for the purpose of producing a collimated beam.

The linkage system has yet to be fully designed and tested. Further investigation should indicate a design which will be suitable to a large number of standard typewriters.

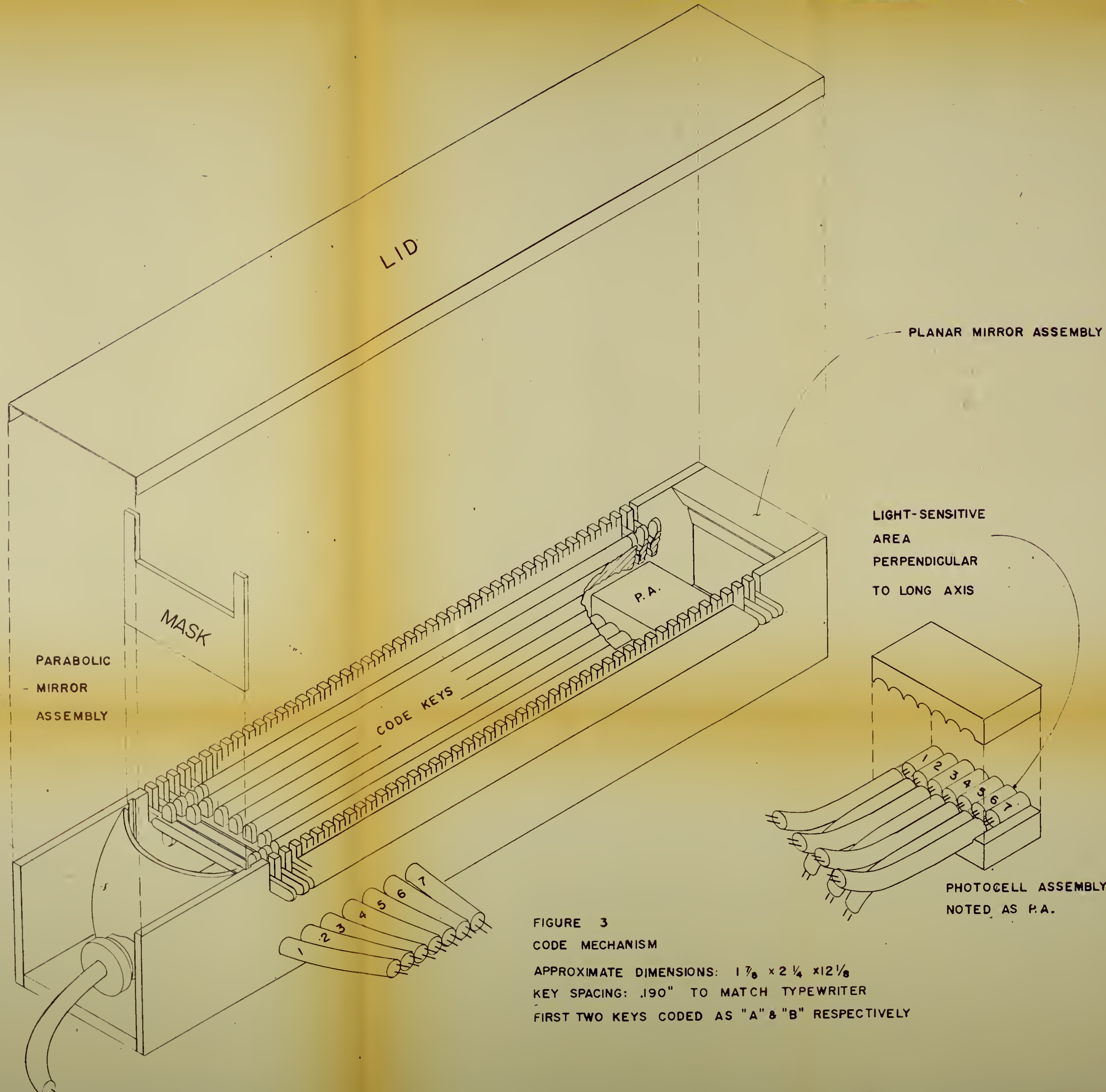


FIGURE 3
CODE MECHANISM
APPROXIMATE DIMENSIONS: 1 7/8 × 2 1/4 × 12 1/8
KEY SPACING: .190" TO MATCH TYPEWRITER
FIRST TWO KEYS CODED AS "A" & "B" RESPECTIVELY

APPENDIX A

AN INTRODUCTION TO BRAILLE

The braille code, illustrated in figure A-1 is made up of a matrix of six raised dots. This matrix is the braille cell. The combination of these dots in any number up to six enables more than the entire alphabet to be represented. With the additional unused combinations, common contractions are constructed. However, in this report, only standard symbol coding is delt with. There are certain symbols in writing which require two cells in braille rather than one. Such a character is the capital letter. The capital letter in braille is similar to its lower case counterpart; the difference is in the addition of one dot in the previous cell which indicates that the cell is to be regarded as a capital. Another such two celled character is the numeral. Two cells are necessary here since the number symbols correspond to the first ten letters of the alphabet.

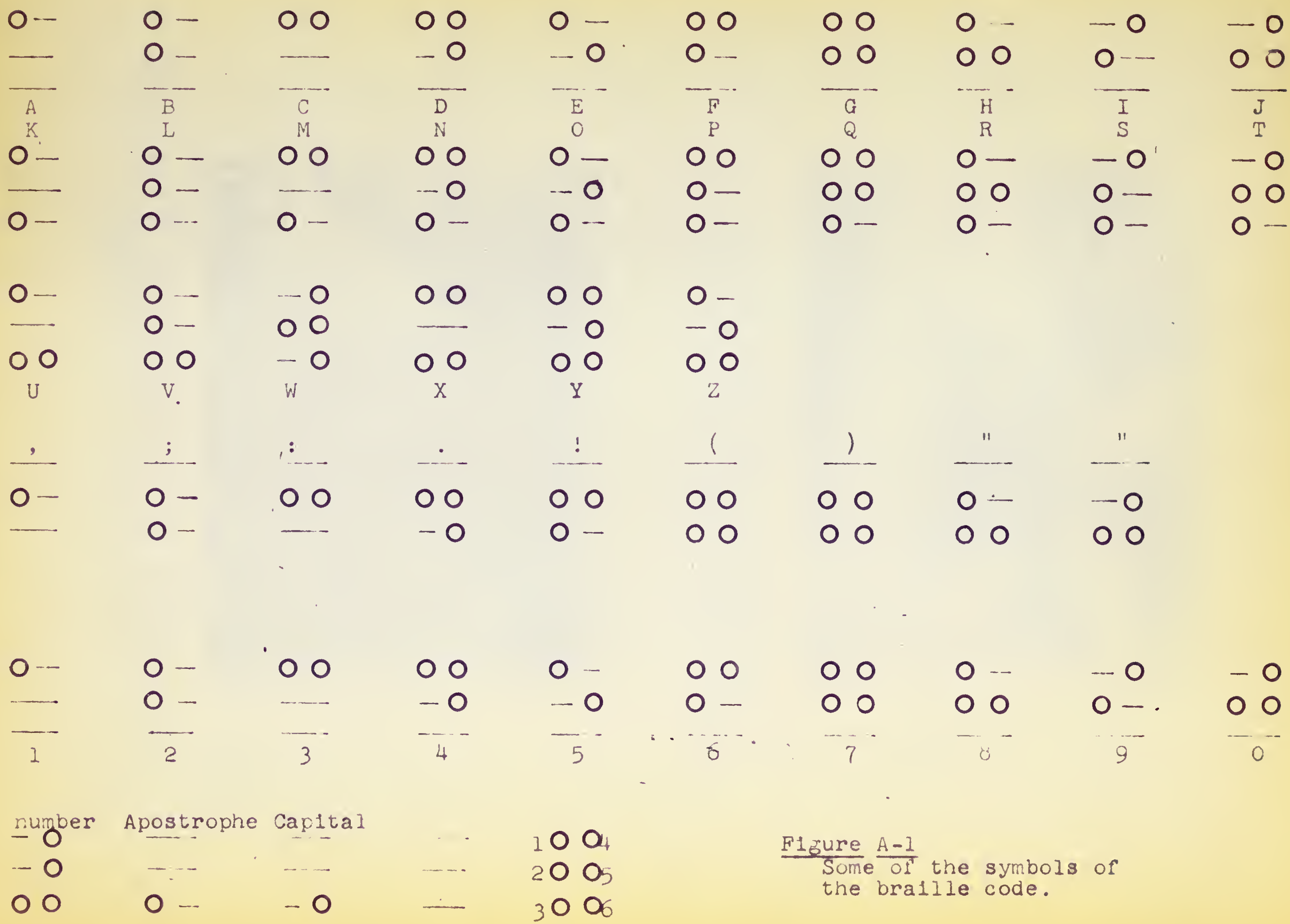
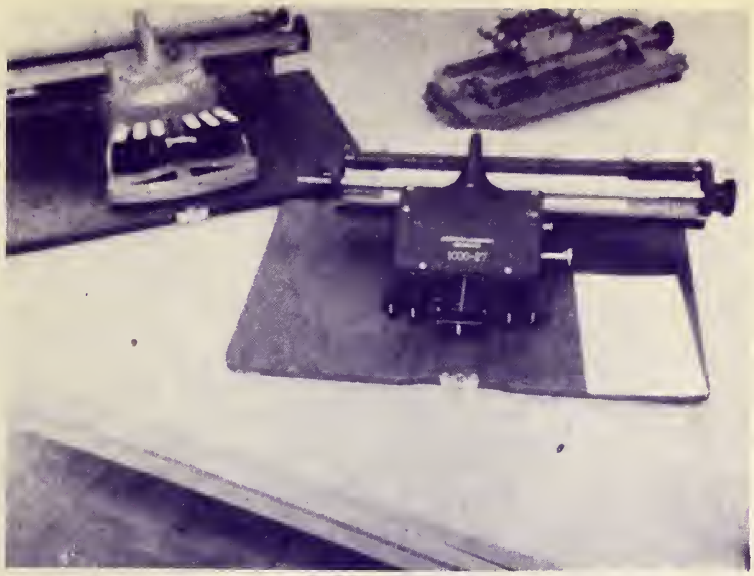


Figure A-1
Some of the symbols of the braille code.

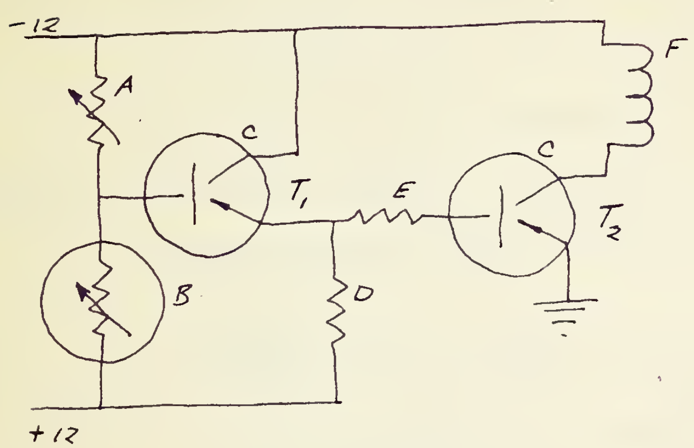


PICTURE A-1: Above are shown three different makes of braille writers. Each requires special training and considerable effort to operate.

PICTURE A-2: In the foreground is the portable electric typewriter for which the prototype converter was designed.

APPENDIX B

DETERMINATION OF CIRCUIT PARAMETERS



I. <u>Photocell exposed to light</u>

Step 1. Place the voltage of the base of T_1 slightly positive - using the rated illuminated impedance of the photocell (1.5 kilohms) and choosing the voltage as +1 volt the result that the trim pot A must be 1.8 kilohms is obtained.

Step 2. Choose resistor D such that the voltage at the base of T_1 is still approximately 1 volt. Since T_1 has a beta of 50, anything up to the order of 10 milliamperes in the emitter will not produce enough current in the voltage divider to alter the base voltage. Therefore D should be $\frac{11\text{ v.}}{11\text{ ma.}}$ = 1 kilohm.

II. Photocell in darkness

Step 1. Assume that the new impedance of the photocell is infinite compared to the 1.8 kilohms of R_A.

Step 2. Assume 20 milliamperes current through the base of T_2 rather than the 3 milliamperes predicted by a beta of 50 in order to assure saturation.

Step 3. Call the current through R_D I_D and assume an effective beta for T_1 of 20, then solve for I_D.

$$\frac{1.8\text{ k.}}{20}(I_D + .020) + I_D \times 1\text{ k.} = 24\text{ v.}$$

I_D is approximately .020 amperes.

Step 4. Solve for the voltage at the emitter of T_1. $I_D R_D$ = 20 volts, therefore the emitter of T_1 is at -8 volts with respect to ground.

Step 5. Adjust R_E in order to drop 8 volts from the emitter of T_1 to the base of T_2.

$$R_E = \frac{8\text{ v.}}{20\text{ ma.}} = 400\text{ ohms}$$

MEASURED VOLTAGES IN EXPERIMENT

	Output off	Output on
- Supply	-12.8 v.	-12.1 v.
Emitter T_1	+ 6.2 v.	- 5.7 v.
Base T_1	+ 6.2 v.	- 5.8 v.
Base T_2	+ 6.2 v.	- 0.5 v.
+ Supply	+12.7 v.	+13.1 v.
Collector T_2	-12.8 v.	0.0 v.

All voltages in table greater than one volt have a tolerance of 0.1 volt and all voltages less than one volt have a tolerance of 0.5 volt. These voltages do not coincide due to the fact that the potentiometer was not set before the test but was, rather, adjusted for optimum operation with the code box.

	DATE DUE		
Reference		Copy	